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PLAN FOR SYSTEMS ENGINEERING OF THE NRD DATA TRANSMISSION SYSTEM

JANUARY 1968

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O. Cardinale

Prepared for

AEROSPACE INSTRUMENTATION PROGRAM OFFICE

ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts



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Project 705B

Prepared by

THE MITRE CORPORATION
Bedford, Massachusetts
Contract AF19(628)-5165

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FOREWORD

This report was prepared by the Communications Techniques Subdepartment of The MITRE Corporation, Bedford, Massachusetts, under Contract AF 19(628)-5165. The work was directed by the Development Engineering Division under the Aerospace Instrumentation Program Office, Air Force Electronic Systems Division, Laurence G. Hanscom Field, Bedford, Massachusetts. Mr. Robert E. Forney served as the Air Force Project Engineer for this program, identifiable as ESD (ESSID) Project 5932, Range Digital Data Transmission Improvement.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved.


Curtis R. HILL, Colonel, USAF
Director of Aerospace Instrumentation
Program Office

ABSTRACT

A proposed systems engineering plan is presented which would be used as a guide in accomplishing systems analysis and engineering to support the NRD Data Transmission System Improvement Program. The need to relate specific performance parameters of the NRD data transmission systems to the mission effectiveness of the range users is emphasized together with the need for a better understanding of the system users' requirements.

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SECTION I

INTRODUCTION

PURPOSE AND BACKGROUND

The purpose of this report is to outline the basic steps that are being taken, in accomplishing the systems engineering and analysis required to support the NRD Data Transmission System (DTS) Improvement Program. This plan is designed to serve as an internal working guide for current efforts in accomplishing the goals described here.

The NRD-DTS has been subjected to system user demands which were not always realistic or justified in some cases. The DTS has been treated in the past by the subscriber as a virtually unlimited resource (in terms of expected performance if not in terms of capacity). In reality, of course, the NTD-DTS contains a limited set of valuable resources which must be allocated in a reasonably efficient and orderly manner to meet the realistic user demands. This, in short, is the essence of the systems engineering effort and plan described in this report.

The principal reason for the existence of the NRD-DTS is to provide support required by the range data subscribers. The overall purpose of a systems engineering plan is to outline the method of arriving at a system configuration and implementation that is based on realistic system user needs.

PROGRAM OBJECTIVES

The primary objectives of the NRD Data Transmission System Improvement Program can be summarized briefly as the following. The first and perhaps most important objective is to determine what the actual NRD-DTS

subscribers' needs are, in terms of their mission requirements and the corresponding operational environment that the NRD-DTS must contend with. These needs are difficult to establish, particularly for future needs and programs. However, the only alternative available is to design a system based on some postulated subscriber needs which may not be valid when examined in terms of the actual jobs to be done by the system.

The second objective is to establish specific NRD-DTS configurations which will meet the range subscribers' needs as established. Several configurations will have to be analyzed and exercised against the established system users' needs and the expected operational environment. In this manner a near optimum system configuration can be established.

The third objective is to develop a system implementation plan. One of the primary requirements that must be met by this plan is the minimal system down-time to convert over to the new system implementation. Another part of this plan is the set of system specifications which would be used to procure the additional subsystem elements required.

System Constraints

Each of these primary objectives must be achieved within the limitations of the following general system constraints. First, the system design and implementation must be evolutionary. That is, the system design must make maximum use of the existing subsystem elements wherever possible. In addition, as stated above, there must be a minimum of system disruption during the implementation phase. In order to meet the requirements for future needs there must also be provisions for orderly future expansion of the system to meet anticipated future requirements.

The second general constraint is the requirement for conformance with DOD/DCA directives. These include system interface standardization to meet the requirements of MIL-STD-188B and, in addition, system compliance with the current military standards for RFI, Human Engineering, and Environmental service conditions. Compatibility with the DOD directives for encryption including compliance with FED-STD-222, must be provided by the modified NRD-DTS. Another constraint is the application of system configuration management practices given in AFSCM 375-1 to all items procured for the system. In addition, overall maintainability and reliability constraints must be established for the system and pro-rated down to the system elements so as to be compatible with the established overall system performance levels for each link availability requirement. These requirements must be translated into specific MTBFs and MTTRs for each element of the system.

Statement of the Problem

The overall problem may be defined by the following three questions:

- (1) What are the DTS tasks to be done and their corresponding performance criteria (expressed in terms of the system users' needs)?
- (2) What are the acceptable quantitative system performance levels for these tasks?
- (3) What changes to the existing NRD-DTS must be made to achieve acceptable performance level for each NRD-DTS link?

The range DTS users' needs provides the fundamental data base for the overall system design and implementation. It is this data base which must be used to develop meaningful answers to the three questions posed above. When the proposed system modifications have been implemented, the overall system

performance will be gauged against the range users' needs as they actually exist, not on postulated range user needs. If the actual range user needs are significantly different from those used to develop the proposed modified DTS, then the wrong problem will have been solved.

Before any headway can be made in solving the formidable systems engineering problems that lie ahead, the overall problem must first be divided into distinct parts or sub-sets that are relatively independent. This is not to imply that the interrelationships between these subsets can be ignored, by any means. It is one of the primary responsibilities of the systems analyst to determine the effects of these interrelationships on the overall systems engineering tasks.

A tentative choice of overall subsets is given in Figure 1. The primary subset (i. e. the independent sub-set) is the Range Users' Needs. The nature of the remaining (dependent) subsets are then derived from this primary sub-set. The dependent subsets are:

- (1) Data Transmission System Tasks
- (2) System Performance Criteria
- (3) System Functional Characteristics

An advantage of this approach is that it provides an effective overview of the whole problem in a single concise presentation, while showing the basic hierarchy of relationships between system requirements, systems parameters and range system range user needs.

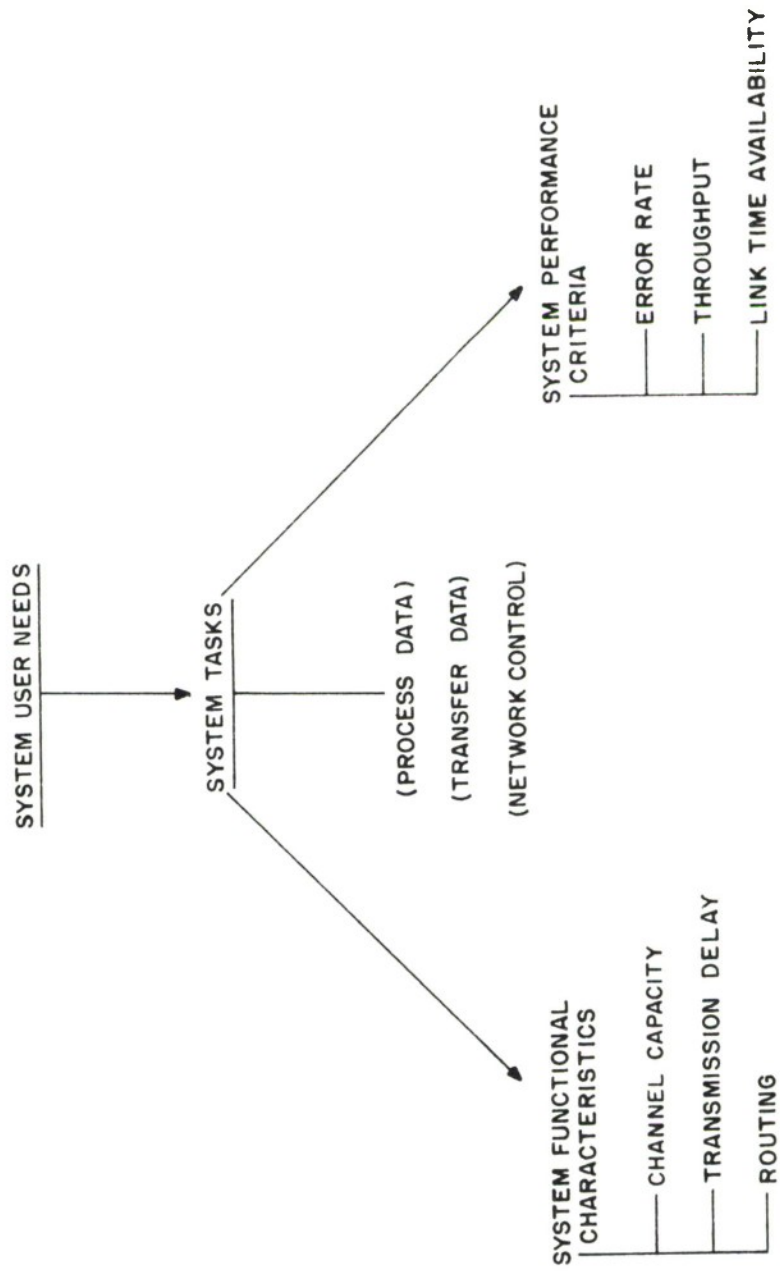


Figure 1. Basic Problem Subsets

SECTION II

DISCUSSION

ESTABLISHING RANGE USER NEEDS

In this section, a method is given for determining the range users' needs, which forms the primary data base for the whole systems engineering effort directed toward improving the existing NRD range data transmission system. This can be done in the following two steps: the first step is analysis of the data transmission system subscribers' needs in terms of expected data traffic loading and data traffic characteristics and the second step is determining those system subscribers' data source and sink terminal characteristics which are pertinent to the range data transmission system design and operation.

Subscriber Source/Sink Characteristics

The subscriber terminals have characteristics of concern to the data transmission system analyst since they directly influence system performance. The subscriber terminals may be classified into the following three categories:

- (1) Sensors
- (2) Telemetry Devices
- (3) Data Processors

It might be argued quite logically, at this point, that the subscriber terminals' characteristics are of no concern to the data transmission system analyst, and in fact this has been the prevalent attitude in the past. However, past experience has shown this to be a short-sighted policy. For example,

at the present time information is being transferred between subscriber terminals that is meaningless to the subscriber and wasteful of a valuable and severely limited resource, namely the data transmission system. Instead of transferring this meaningless data, the channel capacity could be more efficiently utilized by replacing this data with error detection and correction information bits which would significantly improve the information transfer reliability between subscriber terminals. Another shortcoming is the transfer of metric data to more significant figures* than is realistic in terms of the uncertainty in the measurement performed by the subscribers' sensors. For example, it is a well documented⁽¹⁾ fact that the uncertainty in the value of the propagation velocity of electromagnetic waves measured in a vacuum (under precisely controlled conditions) is several parts in 10^6 and for a varying media such as the earth's atmosphere, the uncertainty in this measurement is at least an order of magnitude larger. Transmission of sensor data to a precision greater than this value is again a fallacy which is all too often indulged in by data subscribers.

The point is that the data transmission facilities are a valuable resource which must be utilized efficiently. Therefore, the data transmission system analyst has the right (and duty) to challenge the validity of data being transferred over these facilities. Whenever the data subscriber generates a requirement for transmission of data over these facilities, he should be prepared to defend his needs. All too often in the past, requirements have been imposed on data transmission facilities by data subscribers which were not based on real needs. As a result, considerable effort and expense was needlessly imposed on the implementation of the data transmission system.

*Standard range word for ETR is 25 bits long, implying a range resolution of 3 parts in 10^8 .

The primary sensor characteristics of concern to the data transmission system analyst then would be the following:

- (1) Sensors' range vector data uncertainty.
- (2) Range vectors' time tag uncertainty.
- (3) Maximum sensor data sample error rate acceptable to subscriber data sink terminal.
- (4) Maximum permissible real time delay in transmission of sensor data to subscriber sink terminals.
- (5) Sensors' maximum data sampling transmission rates, and data sample lengths in bits.
- (6) Locations of subscriber sink and corresponding subscriber source terminals.
- (7) Acceptable data transmission link time availability/reliability level.

These parameters or characteristics are sufficient to define the data transmission tasks and performance criteria for the reliable transmission of range sensor data.

The ground telemetry devices used by the ranges can be divided into the following three types: namely TLM command units, TLM receivers, and TLM data demultiplexers. The primary characteristics of these devices that are of concern to the data transmission system analyst are the following:

- (1) TLM data uncertainty.
- (2) TLM data time tag uncertainty.

- (3) Maximum permissible transmission delay between the subscriber source and sink terminals.
- (4) Maximum data sample error rate acceptable to the subscriber sink terminal.
- (5) Maximum TLM data block transmission and acceptance rates, and data block.
- (6) Minimum acceptable data transmission link time availability/reliability level(s).
- (7) Locations of the subscriber source and corresponding sink terminals.
- (8) Acceptable TLM data formats delivered to subscriber sink terminals.

The remaining type of subscriber terminal is the data processor. The primary characteristics of this device that are of concern to the data transmission system analyst are identical to those given above for the telemetry devices. In addition, the following characteristic is also of concern; data processor maximum information transfer rate/capacity available for intra and inter range data transmission.

Range User Traffic Loading Analysis

A method is given here for classifying and describing range user traffic (Figure 2) and logically organizing the study of range data transmission system traffic flow. This arrangement will permit the development of quantitative data transmission performance levels in terms of the range users' expected demands for each specific subclass of transmission link by the NRD-DTS.

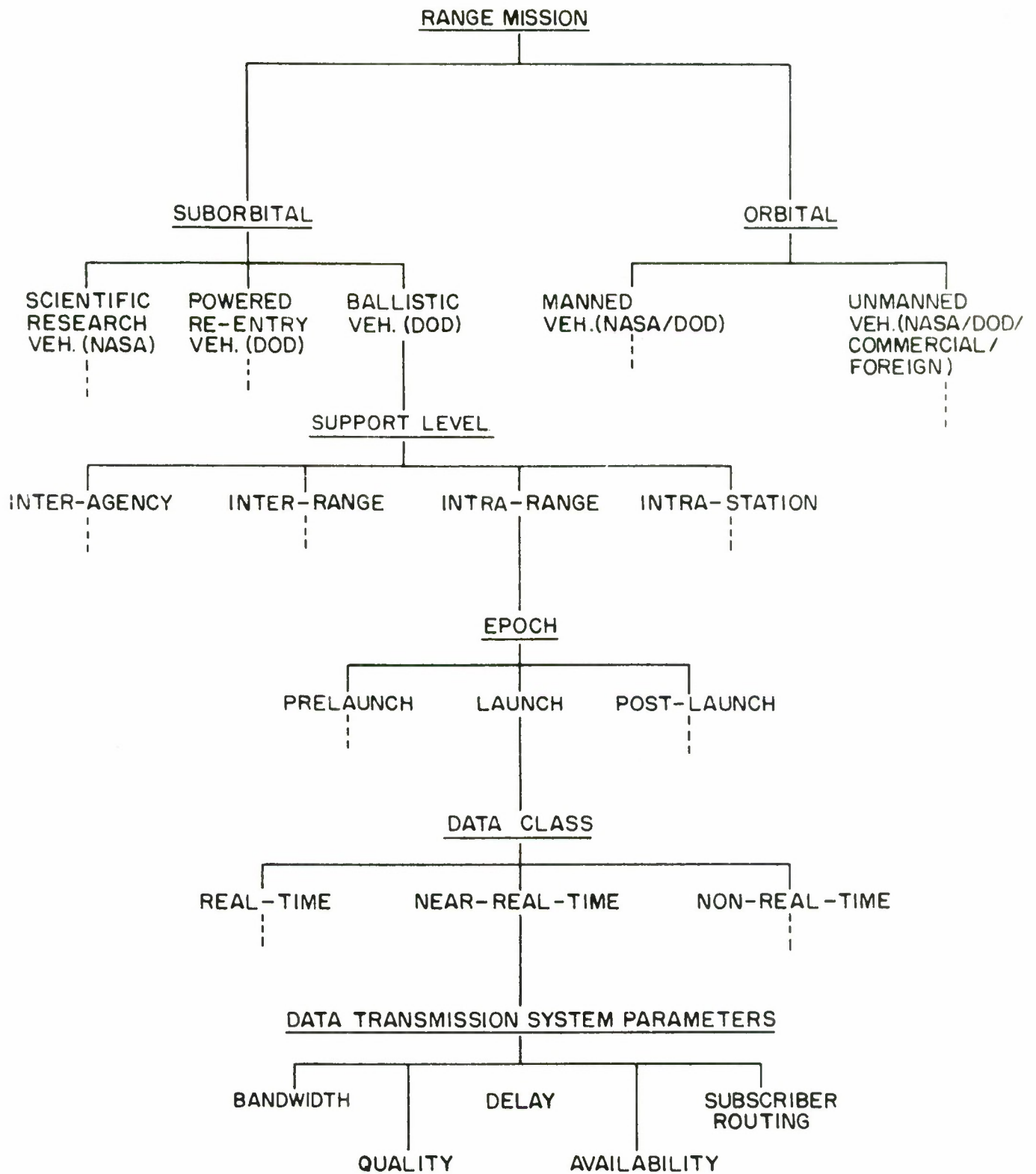


Figure 2. NRD-DTS Traffic Analysis

Each of the missions supported by the NRD ranges are divided into sub-orbital vehicle missions and orbital vehicles missions. Each of the five resultant mission types is separated into four different levels of support varying from intra-station data transmission to inter-agency data transmission. Again each of these four support levels is further classified into three different time epochs (i. e. , pre-launch time period, launch time period and post launch time period). For each of these three time periods there are three common classes of data transmission which are again classified in terms of time characteristics. In this case the real time data is that data which is concerned with command control function; near real time data is concerned with information data using synchronous data transmission techniques permitting some time delay (up to approximately 10 seconds) in transmission. The remaining transmissions are classified as non-real time, such as post flight data, administrative teletype, etc.

A total of 180 different categories of range data transmissions are established here of which there are approximately 25 classes which include over 80 percent of the NRD data transmission links. The next step is to determine tasks in terms of the NRD-DTS functional characteristics and the performance criteria, i. e. , link quality, availability, data rates, delay and routing requirement, based on the range DTS users' needs. Thus the needs of the data subscribers are quantitatively established on a functional link-by-link basis.

Data Transmission System Tasks

The first primary task established was information data processing which includes frequency/time multiplexing, modulation, error control, information signal equalization, signal security processing and signal timing

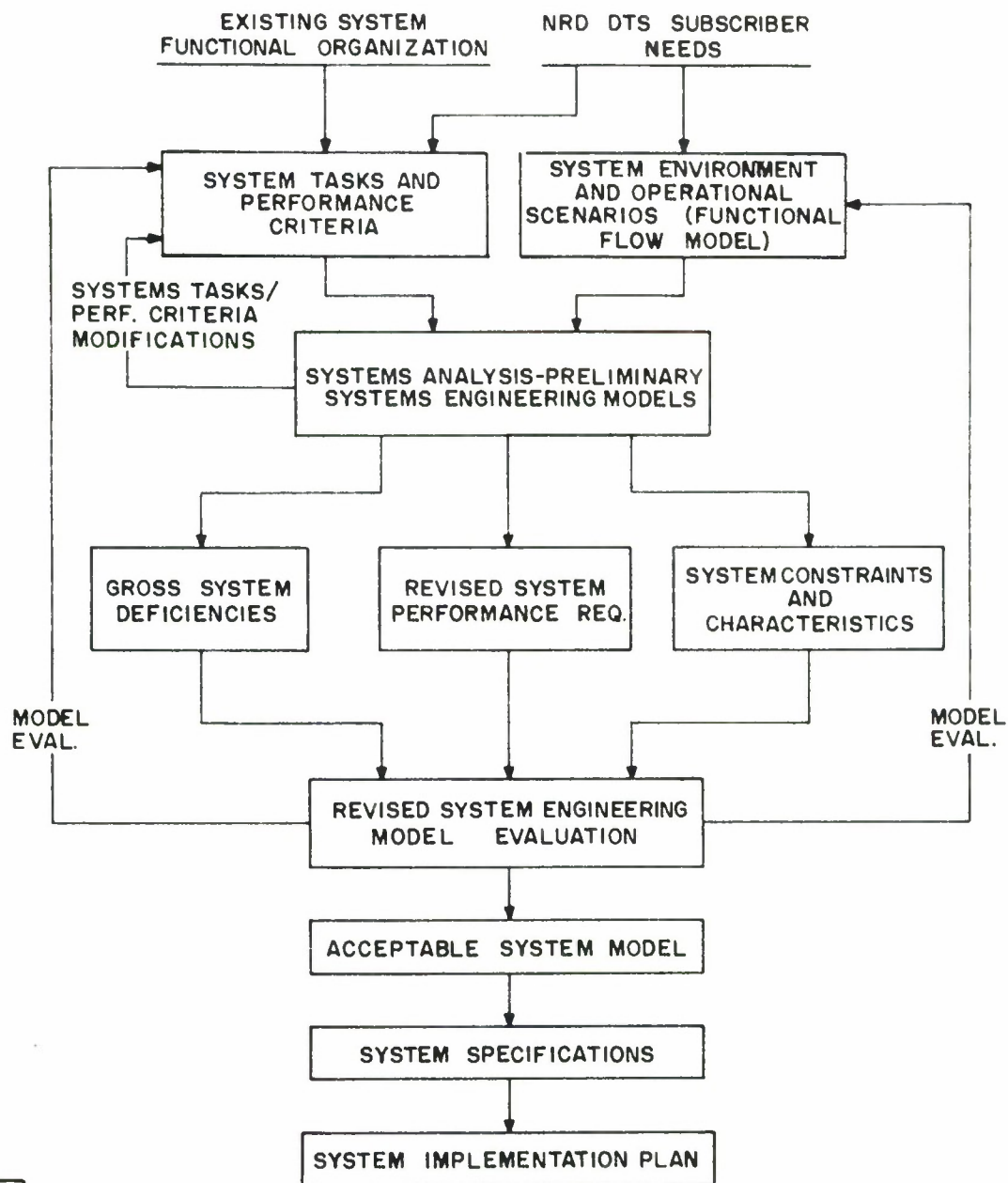
functions. The second primary task established was information data routing which includes circuit addressing, switching, signal transmission, and transmission circuit equalization. The third primary task established was network control which includes information data signal quality monitoring/display, link quality monitoring/display, station status monitor/display, transmission mode selection, circuit selection control, and error control mode selection.

SYSTEM ENGINEERING TASK FLOW

The basic plan of attack for the overall systems engineering job is shown in Figure 3. The primary data base is formed by two groups of information:

- (a) Subscriber operational support needs.
- (b) Existing functional organization of the NRD range systems, including the NRD-DTS.

The basic method of establishing the subscriber needs has been the subject of the previous section of this report. Notice that an a priori assumption is made that the system tasks can be established with the existing knowledge of subscriber needs. However, these can (and will be) changed if further analysis of subscriber needs indicates such a change is necessary. This would be one output of the systems analysis phase of the task flow. In fact, system tasks and environment are continuously under evaluation through the systems engineering model evaluation phase until an acceptable system model is developed as shown in Figure 3. The next step then is to consider the system environment and operational scenarios in terms of function flow models.



IA-22,740

Figure 3. Systems Engineering Task Flow Diagram

Functional Flow Model

One of the most important tasks that must be accomplished before a realistic system model can be developed, is the determination of the functional flow diagram which describes the basic sequence of events required to support a range user launch and flight, insofar as the data transmission system is concerned. What is of concern here is the pattern of data traffic flow for various parts of the NTD-DTS. This information data base will be used to develop the functional flow model for both the ETR and WTR data transmission systems. Once these are established and verified, a realistic working model of the improved data transmission system can be readily developed.

The first step in developing functional flow models is to identify the function and types of models to be developed. There are two basic models which are to be developed for this purpose, namely: information flow models and the operational flow models. The basic information flow models are shown in Figure 4, for the central range station and in Figure 5 for the remote range station. In each model the pertinent data which is related to the data transmission system is the information flow through each element identified in the mode. How each box interacts on the information that flows through it, and what impact the performance parameters of the data transmission system elements have on the overall mission effectiveness, is the fundamental question that must be answered for each individual model. In order to answer this question, it is necessary to identify the existing/proposed DTS elements and their configurations in the model. One important fact must be recognized about the data transmission system (which is true in general for any data transmission system); the performance of the data transmission system by itself has no meaning. It is only when this performance is related to the

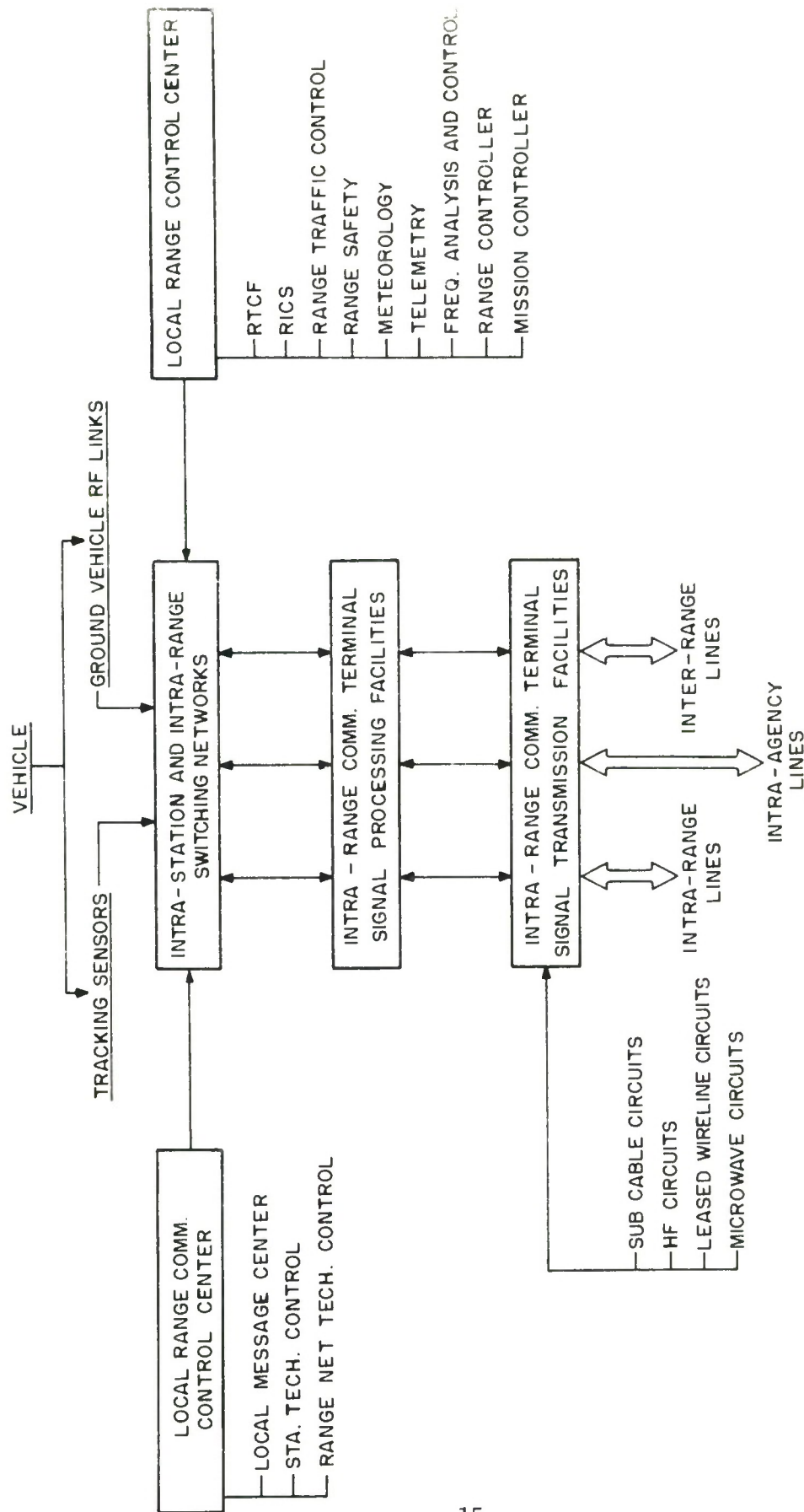


Figure 4. Information Traffic Flow Model
Cape Kennedy

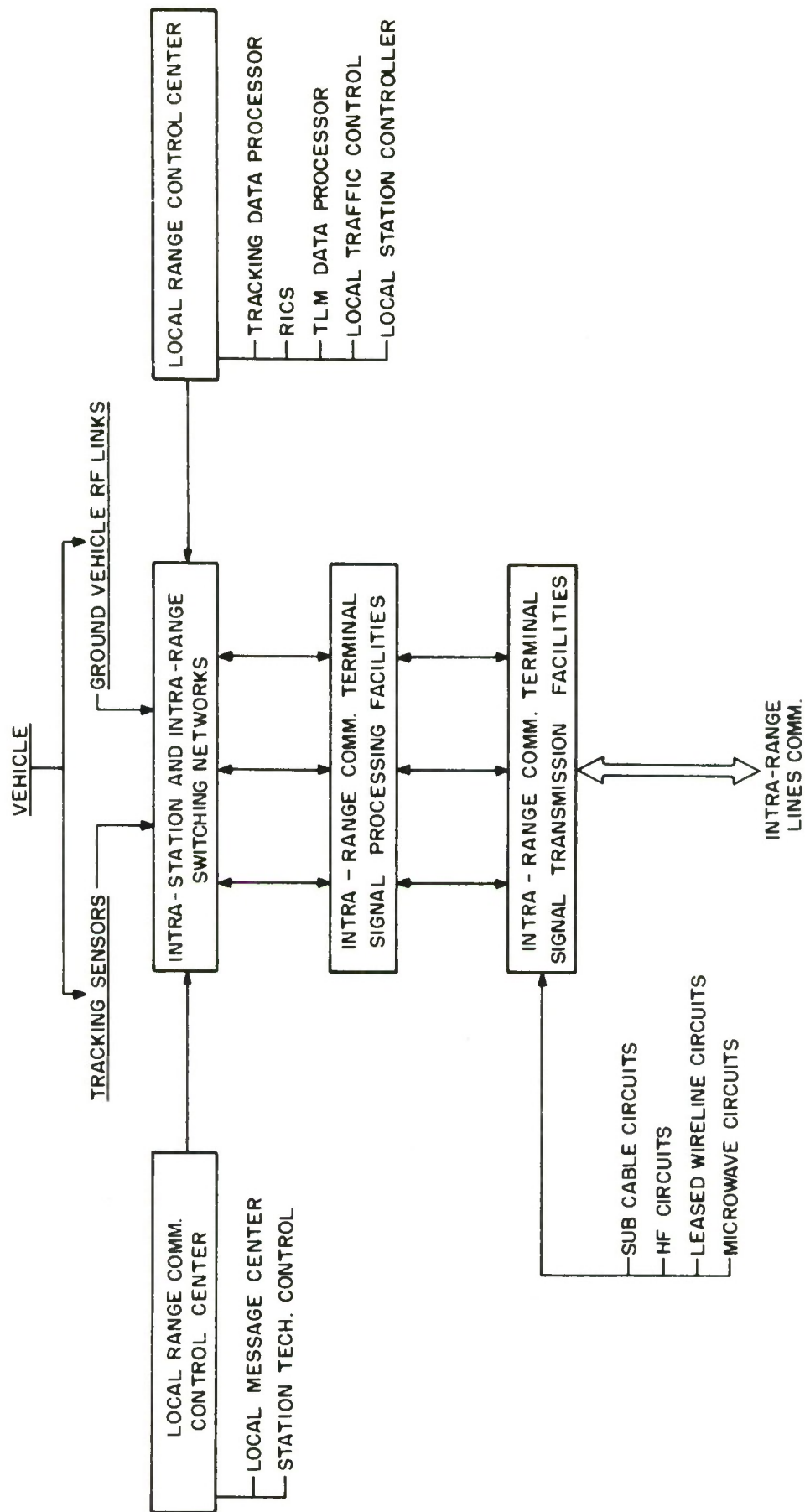


Figure 5. Information Traffic Flow Model
Downrange Stations

subscribers' mission or tasks that this DTS performance takes on any significance. Only by relating throughput, error rate, delay and link time availability to the mission of the system users, can any real performance criteria and requirements be established for the NRD-DTS.

The other type of model to be developed is shown in Figure 6. This is the operational flow model which shows the sequence of events and supporting tasks to be performed by the DTS elements. The particular time flow of events will depend on the class of mission that is being supported by the range. Reference to Figure 2 shows that there are five different classes of missions and four different levels of support for each of these classes of missions. (A separate model will be generated for each of the five mission classes.) The levels of support required to meet the range users' needs will be identified for each of the system elements shown in the information flow models.

The operational flow models are dynamic models since they show the time relationship of different tasks to be performed by the NRD-DTS, whereas the information flow models are static in nature. With the operational flow models, different environmental factors may be considered in terms of their impact on performance of the support mission to the range user, once the basic model has been set up. The impact of the loss or degradation of different data links can be determined in terms of the range users' mission effectiveness. In this way, the critical paths and elements of the NRD-DTS can be readily established.

Thus far the data transmission system tasks, performance criteria, subscriber needs and operational environment have been considered. Each of these groups of information is an input into the systems analysis phase which is the next phase shown in the task flow diagram. This phase involves

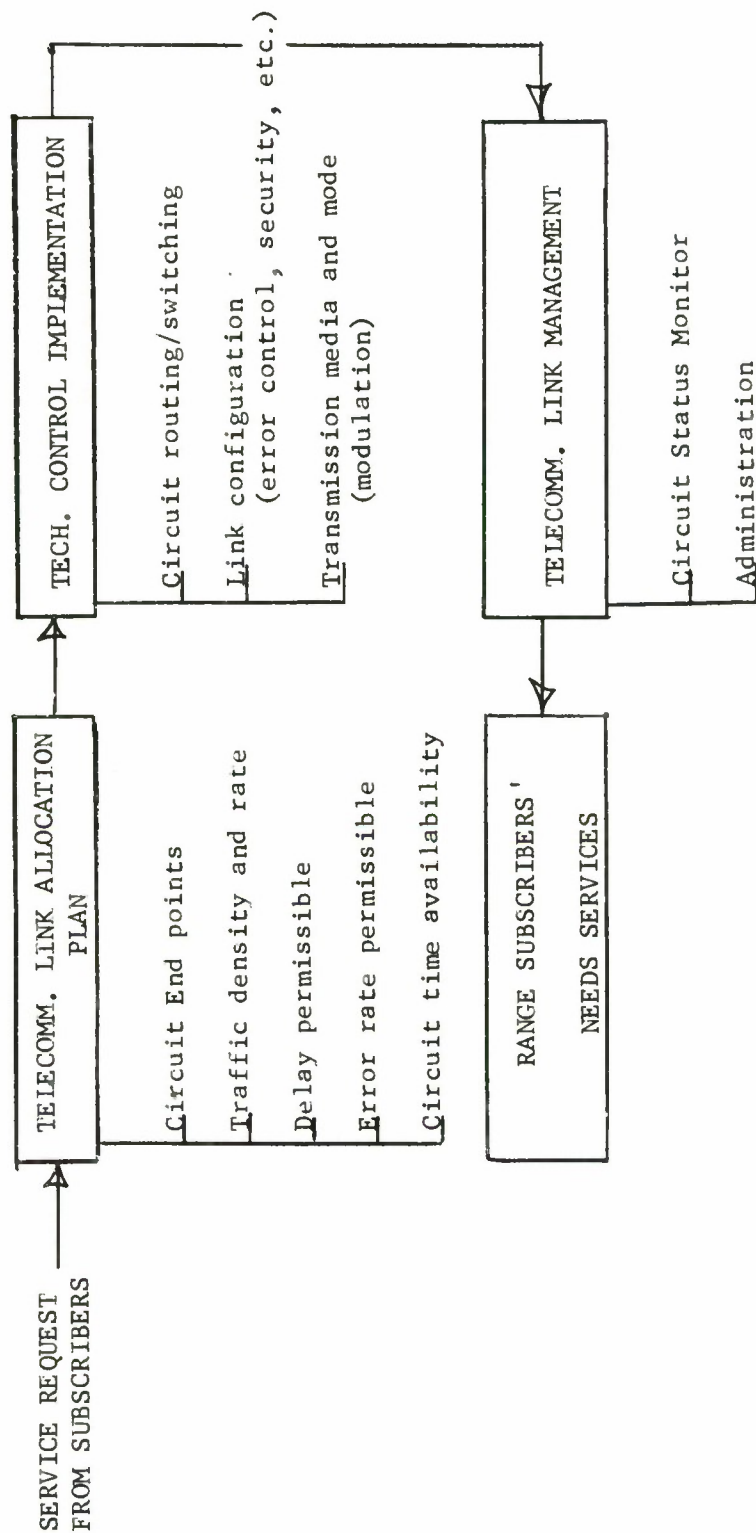


Figure 6. Basic Operations Flow Chart for NRD-DTS

OPERATIONAL FLOW MODEL FOR NRD RANGES DATA
TRANSMISSION SUPPORT NEEDS

Sequence of Events

Thirty days prior to scheduled launch to 2 days before launch.

Planning functions for layout for circuit routing for TTY,
data and voice.

- (a) Manual patching facilities
- (b) Programmable patch (punched cards)
- (c) Semi-automatic switching system (WTR Telecomm.
Switch)

Instrumentation for mission programmed for central station
control/monitor.

- (a) RICS system for ETR
- (b) IDDS system for WTR

Two days prior to launch to lift-off time.

- (a) Transmission of nominal trajectory acquisition data to
dowrange and other range stations.
- (b) Data Transmission circuit checkout functions.
- (c) Transmission of IDDS and RICS data.
- (d) Transmission of range safety input data to RTCF.
- (e) Transmission of vehicle launch/checkout data.

Figure 6. Basic Operations Flow Chart for NRD-DTS (Continued)

(f) Transmission of supporting administrative traffic.

- (1) Network control (Telecomm.)
- (2) RICS and IDDS network control
- (3) Frequency analysis and control data
- (4) Meteorological data
- (5) Range traffic control data
- (6) Mission controller traffic

Lift-off to Range Safety Zone Clearance time.

- (a) Real time range safety trajectory data transmission.
- (b) Vehicle quick-look health telemetry data transmission.
- (c) Updated tracking acquisition data to downrange stations.
- (d) Sensor near real time tracking data to range central station.
- (e) Vehicle command-control signal transmission.
- (f) Administrative range traffic.
- (g) Vehicle telemetry data.
- (h) Payload telemetry data.

Range Safety Zone Clearance to End of Mission time.

- (a) Near real time tracking data transmission.
- (b) Acquisition data transmission.
- (c) Vehicle/payload command-control data transmission.
- (d) Vehicle/payload telemetry data transmission.
- (e) Vehicle/payload impact location; recovery vehicle vectoring.
- (f) Administrative Traffic transmission.
- (g) Non-real time data traffic transmission.

Figure 6. Basic Operations Flow Chart for NRD-DTS (Concluded)

the task of digesting the information inputs described and generating preliminary systems engineering models of the proposed (modified) NRD-DTS.

Systems Analysis

The systems analysis is performed in terms of the previously derived NRD data transmission tasks and operational environments. The systems engineering models to be derived will represent the first cut at the design of the improved NRD-DTS. One thing that must be established is a concurrence on the jobs to be done by the NRD-DTS, and a set of baseline performance requirements. The functional flow models developed in the previous phase of the task flow will be used as the basic tools to develop the engineering models. Engineering models of various types of data transmission links, including major transmission media, subscriber interfaces and intra station data transmission systems have already been considered in previous MITRE reports⁽²⁾. Implementation techniques for the following classes of data links are to be modeled to establish expected operational link configurations and performance levels. The links are classified in terms of the following parameters:

- (1) Transmission delay
 - (a) Real Time
 - (b) Near Real Time
 - (c) Non Real Time
- (2) Transmission Bandwidth
 - (a) TTY links
 - (b) Voice (high speed) data links
 - (c) Wideband data links

(3) Transmission media

- (a) HF links
- (b) Leased wireline links
- (c) Microwave links
- (d) Submarine cable links
- (e) Intrastation multipair cable

A significant amount of work has already been accomplished in these areas by MITRE⁽³⁾. The primary effort is to make use of this information that is already available to establish current limits on performance of NRD data transmission links. An upper limit is established on requirements that may be realistically met and areas which require further development to meet current and future range user needs will be indicated.

In particular, engineering models of the range communications control centers and their corresponding tasks for both the central and remote stations will be developed. The function of these centers is to allocate and manage the resources of the NRD data transmission system under its cognizance and control to meet the needs of the range users. The management tasks performed by these centers include the following:

- (1) Circuit status monitoring
- (2) Circuit control
- (3) DTS administration

The circuit status monitoring functions include determining whether the circuits are operational or not, whether or not they are busy and the routing status of these circuits. A circuit is considered to be operational when a

predetermined minimum acceptable performance level has been achieved. This is determined by the tech control facility that is connected to each RC³. Control of circuits includes modulation and transmission media selection, switching and signal conditioning and processing. The DTS administration includes range user contact, range station coordination, range user coordination, range controller coordination and mission controller coordination.

An important question arises concerning evaluation of the engineering models that are to be developed. What is the criteria to be used to evaluate these models? There are several approaches that can be taken to answer this question. One method is to take the range users' needs as specified and measure performance in terms of expected error rate, link time availability and throughput for each link. This assumes that the user needs are inviolate. A more realistic approach is to have the range users back up their specified requirements with specific analyses which relate performance of the NRD data transmission links vs. mission effectiveness. In this way a reasonable match between the real needs of the range user and the expected performance of the NRD data transmission system may be realized. Without this approach, the applications of systems engineering to the NRD data transmission system design would be little more than an academic exercise insofar as meeting the real needs of the range user is concerned.

There are three important outputs from the system analysis task: gross system deficiencies, systems constraints and characteristics, and revised systems performance requirements (where necessary). Again it is pointed out that it isn't necessary to exhaust each task of the flow chart before developing the next step or steps. For example, there are several gross systems deficiencies that are identified here which didn't require extensive preliminary study efforts. These are identified below as follows:

- (1) Teletype data transmission system
- (2) Range Communication Control Center Technical Control
- (3) Circuit/message Routing and Switching
- (4) Data Transmission System Operational Configuration Management

Both the ETR and the WTR make extensive use of these (TTY) types of data links for non-real-time data transmission needs. The circuits as they are now configured use manual patching and quality monitoring as well as manual traffic routing and message handling. Either dedicated circuits or message routing through the TTY message center is used. In the latter case, message routing is handled on a torn tape basis, with resultant untimely delays caused by frequent occurrence of peak traffic loads and message header errors. Further, the transmission facilities use inefficient frequency shift key modems with ARO in some cases for long haul links. None of the TTY end instruments used will meet the requirements of FED-STD-222 for red equipment, unless extensive and expensive modifications are made.

Range Communication Control Center Tech. Control

Both ETR and WTR currently perform tech control functions on a manual control, passive quality monitor basis which is totally inadequate for future needs as projected by the NRD planning documents. Current quality monitoring functions are performed on the AT&T basis, i. e. , no action is taken until the customer complains about transmission link quality. There is practically no on-line quality monitoring performed for either voice channel data links or teletype data links. Error control devices are not being procured for the ranges, together with multi-mode modems. However, the

necessary operational facilities to take advantage of the flexibility offered by these devices is lacking. Centralized link quality monitoring is needed to perform on-line quality monitor functions and also perform rapid subsystem checkout to minimize fault isolation time for the data transmission link as a subsystem. Specific on-line quality monitoring techniques must be developed before such a system can be implemented. For example, data eye pattern measurements may be taken on-line to measure intersymbol interference levels. One problem which presents itself is the fact that if the quality monitoring is performed on the black side of the data link, knowledge of the information content cannot be used to perform quality monitoring. This will be a particular problem with voice circuits that are encrypted. Specific techniques must be developed to rapidly determine whether data is out of synch, intersymbol interference levels, and information channel signal to noise ratio.

Data Transmission System Operational Configuration Management

The combined application of error control and data compaction techniques together with specific modulation techniques will require an integrated approach to configuration management of the NRD-DTS. In other words, none of these three techniques can realistically be treated independently of the remaining two since they are all closely interrelated in terms of overall system performance. As a consequence, operational rationales must be established to determine how these combined techniques may be used and under what conditions. This must be combined into the link quality monitoring functions performed by the Range Communication Center Tech Control facilities, together with the proper quality monitoring functions.

Automatic switching facilities now being provided by the Range Comm. Control Centers for both WTR and ETR will require a central configuration management control function to be performed by the Tech Control Facility.

This means that monitoring of circuit status, quality and requirements will be needed, on a centralized basis, for voice data and teletype circuits as well as special purpose circuits such as video monitor and wideband data transmission. The overall objective is to provide a rapid system reconfiguration in minimum time for new mission requirements and changes which occur during the actual mission time period, such as transmission line faults, mission reorientation, etc.

Circuit/Message Routing and Switching

Neither the ETR or WTR has fully realized the capabilities of installed switching plant facilities. The primary problem has been lack of an overall systems integration of these switching facilities to meet specific range user needs. For example, on the WTR the IDDS system is now capable of handling four simultaneous missions; however, the range safety system limitations of the RTCF are such that only one mission at a time may be handled. In addition, these facilities have not been extended downrange to include the range instrumentation ships or the down-range stations. The WTR telecommunications switching system provides rapid turn around time but lacks the programmable features of the corresponding switching system developed for the ETR. On the other hand, the ETR switching system does provide the programmable feature but lacks the rapid turn around time of the WTR facilities. Clearly, a combined engineering approach to both systems would have resulted in an optimum system for both ranges.

Pursuing the IDDS - Range Safety system mismatch problem further, it is found that the principal reason for the limitations on the Range Safety system are due to the computer iteration time to calculate each vector for the launched vehicle position. In turn, the uncertainty that exists in the computer input tracking data resulted in considerable processing of the data

to smooth out errors and obtain a best estimate of the vehicle trajectory. Here is an example of error correction using the most difficult method. If error correction were to be applied to the incoming data prior to introduction to the computer, this computing cycle time could be reduced significantly. Examination of existing formats for this data show that error control could be introduced with little or no reduction in input information rate to the computer. Here is an example where knowledge of how the subscriber handles data can be used to improve overall system performance of the range by engineering improvements into the data transmission system which will provide a pay-off to the DTS user.

Revised Model Evaluation

The next stage of the system engineering task flow is the evaluation of the revised engineering model of the NRD-DTS against the systems tasks and operational environment previously developed. Here the model is evaluated by exercising the proposed system against the operational scenarios to determine that all the system requirements can be met. Once this criterion has been established then a cost effectiveness analysis must be made to determine system performance vs cost and incremental system performance improvement cost sensitivity. All of the standard tools of system analysis can be brought to bear on the problem. The question of how finely detailed an analysis should be performed is left to the needs and desires of the NRD.

Once an acceptable system configuration has been established and agreed upon, the next step is to carry out the system implementation. This will consist of generating the system performance specifications and the specific equipment specifications for that hardware to be procured. Here again, this process can and probably will be carried out on an incremental basis. The purpose of the systems engineering tasks flow chart is to help

assure that the incremental systems engineering process will ultimately converge into a complete system which will function satisfactorily rather than a patchwork of separate subsystems which are loosely tied together to form some ill defined conglomerate system.

SECTION III

SUMMARY AND CONCLUSIONS

A proposed plan is presented for accomplishing systems engineering tasks to develop an improved NRD data transmission system. The primary task of systems engineering is to develop an implementation of NRD data transmission facilities which will meet the current and near future needs of range users, in a reasonably efficient manner. The essence of this plan is a logical approach to the development and definition of the range users' needs as a primary data base. These needs are developed in terms of specific NRD data transmission system characteristics, tasks and performance parameters.

Another factor that must be dealt with is the characteristics of the data subscribers' terminals which are directly related to the NRD-DTS. The thesis is proposed that it is meaningless to talk about the performance effectiveness of the NRD-DTS by itself; this must be related to the effect that NRD-DTS has on the mission effectiveness of the system user. It is not proposed here that the NRD-DTS designer must delve deeply into the working of the range user and his mission requirements. However, it is proposed that the NRD-DTS designer require that the range users justify their needs in terms of the overall mission effectiveness and the performance of the NRD-DTS. The NRD data transmission system is a valuable resource which must be allocated and controlled in a manner such as to achieve maximum mission effectiveness for the system users.

A method is given for developing a systems engineering model for the NRD-DTS which will perform the job discussed above. The primary inputs to this task flow are the subscriber needs which must be established by the

system designer. System tasks and performance criteria are developed together with system constraints and characteristics. Gross problem areas are identified and described, together with revised system performance requirements, using functional flow models. The output of the system engineering flow tasks are an acceptable system model and system specifications and an implementation plan. The utilization of this proposed plan to achieve the goals described herein will help to assure a fair degree of success in achieving the objective of an improved NRD-DTS which will provide the range users with a significant improvement in overall mission effectiveness.

REFERENCES

1. E.R. Cohen, J.W. DuMond, The Fundamental Constants of Physics, Volume 25, 1956, page 180, American Journal of Physics.
2. O. Cardinale, L. L. Stine, The Application of Error Control to NRD Digital Data Transmission Links, ESD-TR-67-377, AF 19(628)-5165, Bedford, Massachusetts, The MITRE Corporation, 1 December 1966.
3. K. Brayer, O. Cardinale, The Application of HF Channel Data to the Development of Block Error Correctors, MTP-32, AF 19(628)-5165, Bedford, Massachusetts, The MITRE Corporation, 13 June, 1966.

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13. ABSTRACT			
<p>A proposed systems engineering plan is presented which would be used as a guide in accomplishing systems analysis and engineering to support the NRD Data Transmission System Improvement Program. The need to relate specific performance parameters of the NRD data transmission systems to the mission effectiveness of the range users is emphasized together with the need for a better understanding of the system users' requirements.</p>			

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